Air Force Institute of Technology

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Solutions Analysis for Helicopter Brownout

9th SE Conference
Oct 2006

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U.S. AIR FORCE

Overview

- **Background (Helicopter Brownout)**
- **Requirements**
  - **Mishap Analysis**
  - **Operational Tasks**
- **Solutions Analysis**
- **Conclusion**

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Prescribed by ANSI Std Z39-18

Hovering Flight

Not as easy as it looks

Changing flight dynamics during approach to hover require large control inputs

Flight Controls

- Main Rotor Thrust Axis
- Main Rotor Thrust Magnitude
- Directional Control Inputs (Anti-Torque)

All 3 Controls are Interdependent

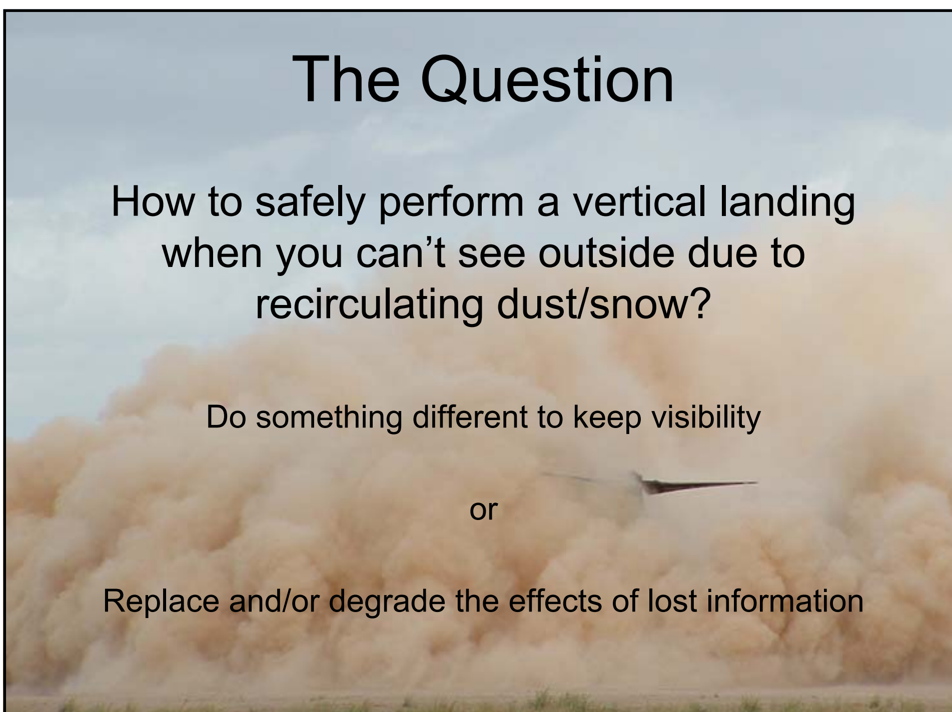
Flight Regime

- Static Instability
- Dynamic Instability
- Constant Perturbations

Detect Aircraft Position & Motion State → Assess Desired vs. Actual State → Make Control Inputs →

Continuous Control Loop

Pitch + Power ≠ Aircraft Control



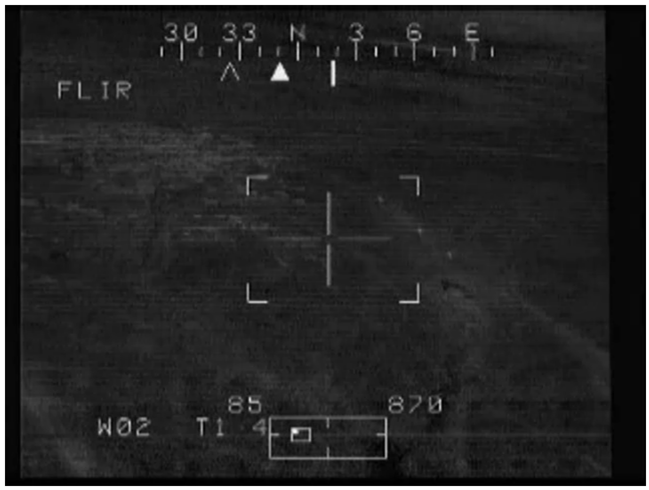
Do Something Different to Keep Visibility

- Land fast to stay ahead of the dust cloud
  - Requires suitable long flat/smooth LZ
  - Requires High Decel Rates at touchdown
  - Dependent on surface winds
  - Aircraft Specific
    - Allowable Landing Attitude (Deceleration)
      - H-60, H-46, H-47 Good (Tail Wheels)
      - MH-53M, Bad (No Tail Wheels)
  - May or may not work out well in formation

Do Something Different to Keep Visibility

Sometimes it works…

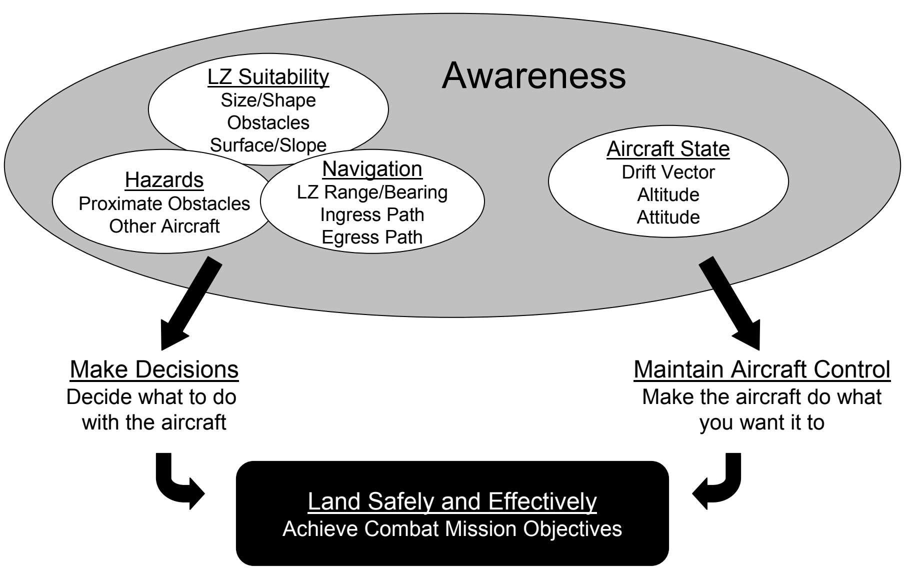
Do Something Different to Keep Visibility



Sometimes it doesn't work

Replacing Lost Information

(and degrading loss of capability)



Replacing Lost Information
(and degrading loss of capability)

- **Aircraft Navigation Systems**
  - GPS/INS, Doppler, Radar Altimeter
  - Mission Computer (Waypoint Navigation)
- **Low Speed Aircraft Control Symbology**
  - Drift Vector, Vertical Velocity, Altitude, Heading, etc.
- **Geospatial Information (What's out there?)**
  - Digital Map (Imagery, Terrain, etc.)
  - Sensor Information (FLIR, Radar, etc.)
- **Reduced Aircraft Control Workload**
  - Stability Augmentation
  - Self Contained Approach Guidance
  - Coupled Approach/Hover Capabilities

V-22 Hover Display

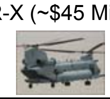
What can be done to improve the situation?

Mishap Analysis
Long known problem, just more prevalent

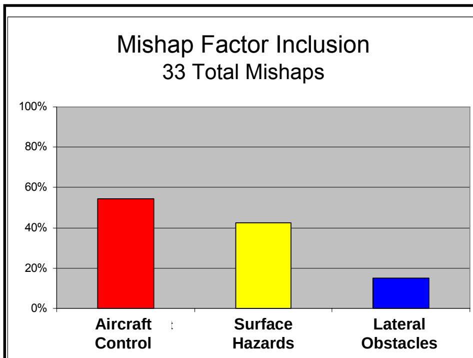
- 33 Identified USAF Mishaps (1971 – 2006)
  - Loss of effective visibility causal
  - Landing/Takeoff phase of operations
  - HH-3E, MH-53H/J/M, HH-60G & UH-1F
- Mishap Costs
  - $72M Total pre 9/11 (30 Years)
  - $72M Total post 9/11 (5 Years)
  - DoD Costs estimated at $100M per year
- Mishap Factors
  - Inadequate Aircraft Control
  - Undetected Surface Hazards
  - Undetected Lateral Obstacle

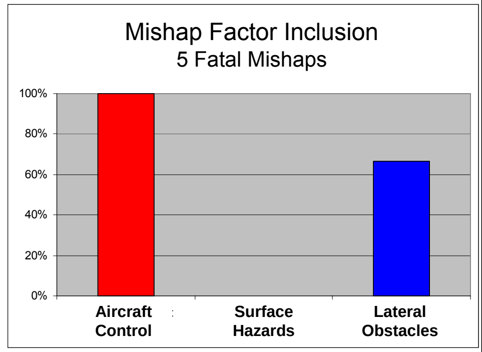
1980 - Desert One (Operation Eagle Claw)
Failed rescue of American hostages, Iran

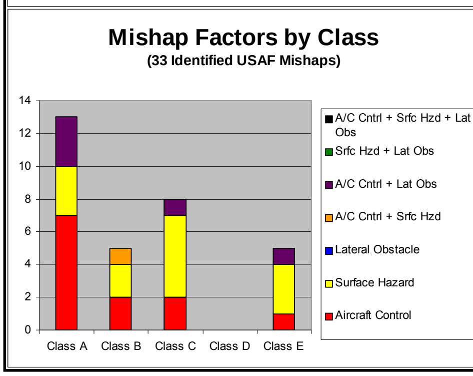
CSAR-X (~$45 Million)



CV-22 ($80+ Million)



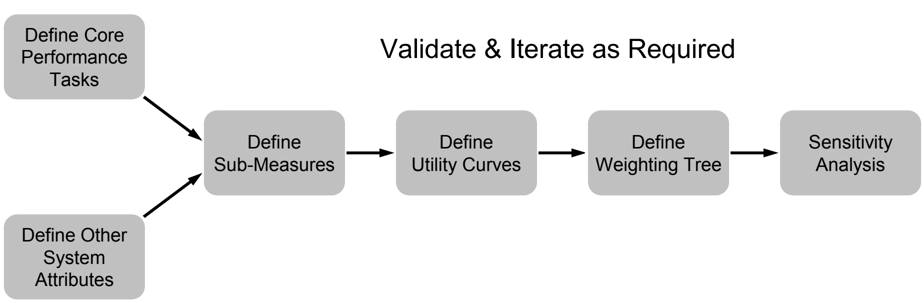




Conclusions

- Maintaining aircraft control is Problem #1
- Better awareness of hazards is important
- Reducing aircraft control workload is key if added sensor information is to be effective
- Capabilities/Tactics that allow zero roll vertical landings could significantly reduce mishaps due to surface hazards

Measurable Requirements



Used to compare relative value between alternative solution sets

Starting point for tech demo system development

Framework for future combat system development

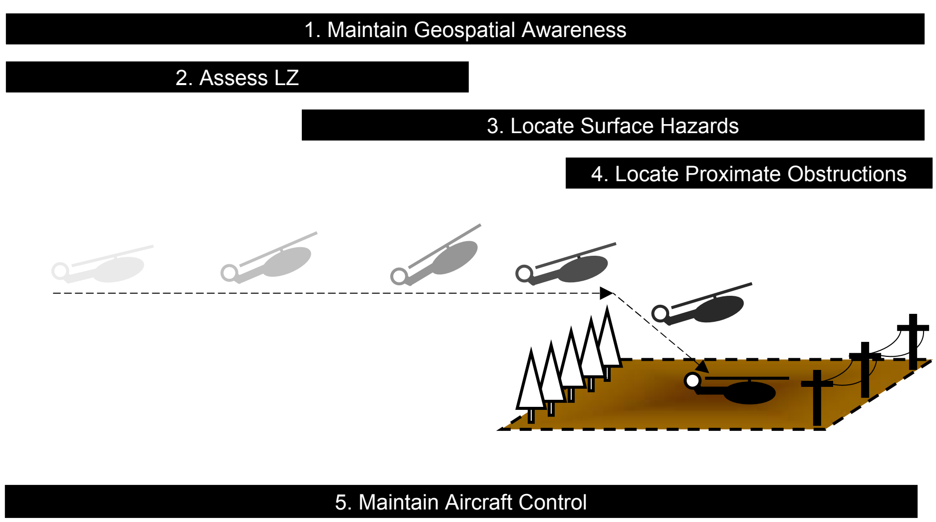
Major Tasks & Attributes

- Core Operational Tasks
  - Maintain Geospatial Awareness of Intended Landing Point
  - Confirm LZ Size & ID/Refine Landing Point
  - Locate Surface Hazards
  - Locate Proximate Obstructions
  - Successfully fly to safe landing point and land/hover as required
- Other Requirements (System Attributes)
  - Human Factors
  - Programmatic
  - Physical Characteristics
  - Sustainability
  - Operating Environment

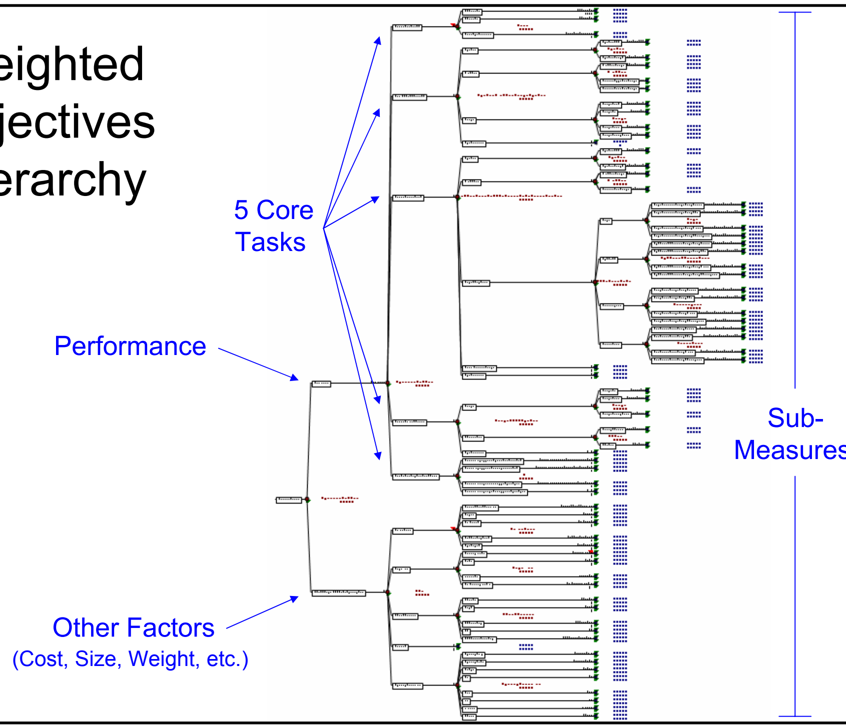
Note: Related requirements sources: AFSOC No/Low Visibility ICD, Cable Warning/ Obstacle Avoidance ICD, CSAR-X CDD

Core Operational Tasks (OV-5)

Execution Timeline

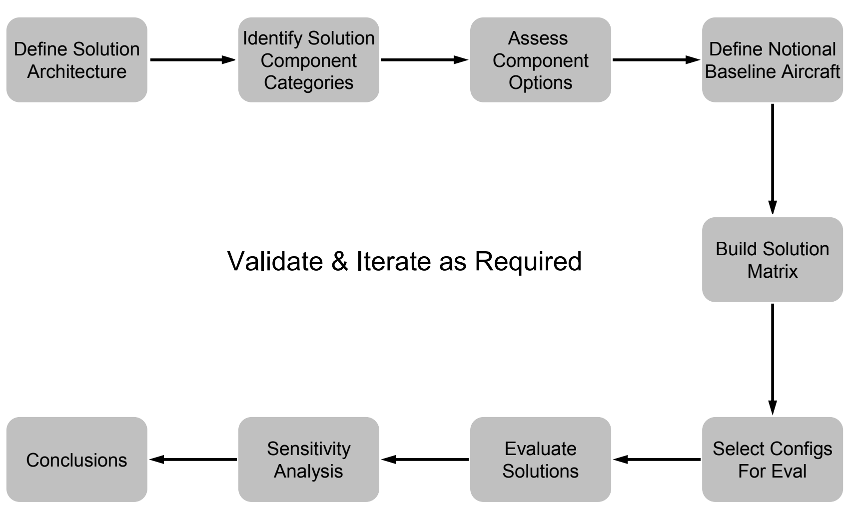


Weighted Objectives Hierarchy

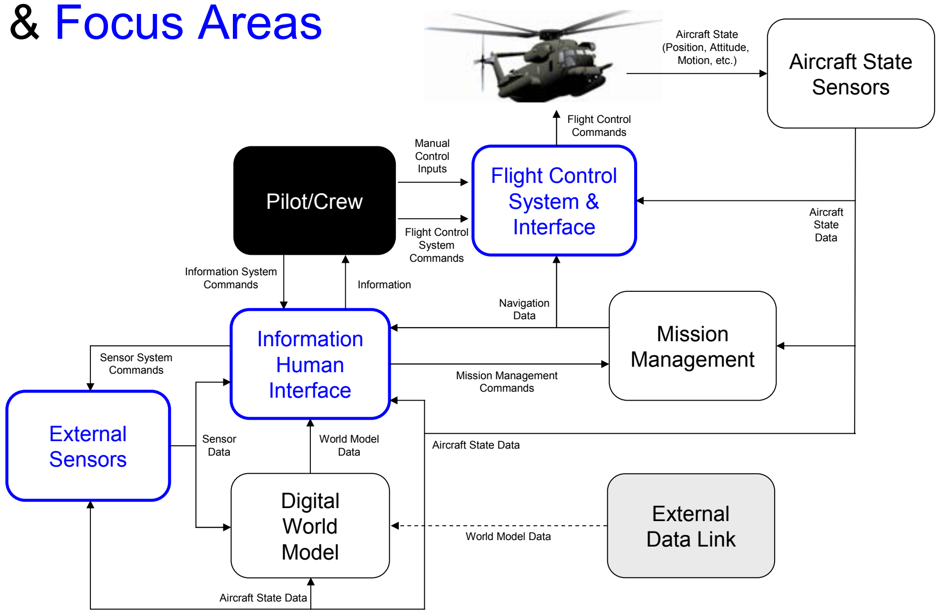


Solutions Analysis

Process Overview



Objective System Architecture (SV-1) & Focus Areas



The Notional Baseline Aircraft

$$\frac{(\text{MH-53M} + \text{HH-60G} + \text{CSAR-X} + \text{CV-22})}{4}$$

=

INS/GPS

Turreted FLIR

Radar Altimeter

Digital World Model
(Digital Map)

Mission Computer / Flight Director

Automatic Flight Control System
(Waypoint Nav & Coupled Approach)

Cockpit Digital Displays (VSD/HSD)

External Sensors

Range, Resolution, Penetration

3D Capable

3D Active MMW
LADAR
Sparsely Populated Radar Array
IFSAR
Active Acoustic System
Image Stereo Pair Modeling

2D Capable

IR Video
Image Intensified (I^2 Video)
Fused IR/I^2 Video
2D Active MMW
Passive MMW (w/ external illuminator)
Passive MMW
SAR
Geo-rectified Digital Image

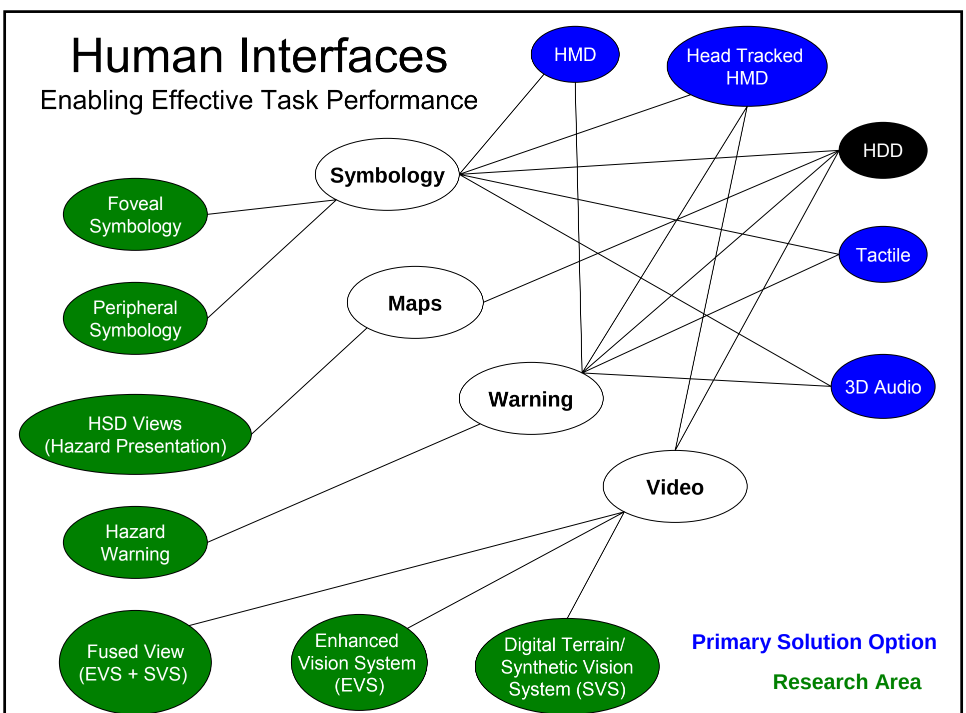
Preloaded Data

Digital Terrain
Vertical Obstruction Data
Digital Maps & Imagery (CIB)

Other Systems

Station Keeping Equipment (range/bearing)
DataLink (aircraft range/bearing + sensor data)

Primary Solution Option **Technology Interest Area**



Aerodynamics & Flight Controls

Effective Aircraft Control

Manual Aircraft Control

Self Contained Approach Guidance
Improved Low Speed Stability (Handling Qualities)
Performance Based Flight Controls
Approach Guidance with Enhanced Obstacle Avoidance

Coupled Aircraft Control

Coupled Hover
Coupled Approach
Coupled Approach with Enhanced Obstacle Avoidance

Aerodynamics

Modeling & Simulation
Visible Null Areas (H-101 & H-53E)

Primary Solution Option

Research Area

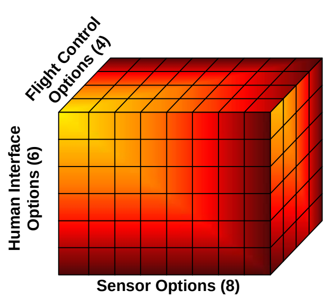
Flight Controls

No Addition

Improved Aircraft Handling Qualities

Coupled Approach with Enhanced Obstacle Avoidance

Coupled Approach with Enhanced Obstacle Avoidance + Improved Aircraft Handling Qualities



Solution Configuration Matrix of 192

Sensors

No Addition

Sparse Array

MMW

LADAR

Sparse Array + MMW

Sparse Array + LADAR

MMW + LADAR

Sparse Array + MMW + LADAR

Human Interface

No Addition

Helmet Mounted Display (Symbology)

Head Tracked HMD (Video & Symbology)

3D Audio & Tactile

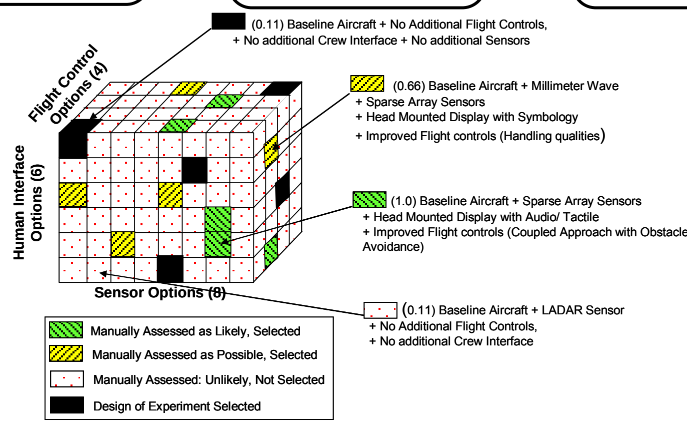
HMD + 3D Audio/Tactile

Head Tracked HMD + 3D Audio/Tactile

Selecting Solution Configurations for Evaluation

Resource/Time Constrained (Can't Assess all 192)

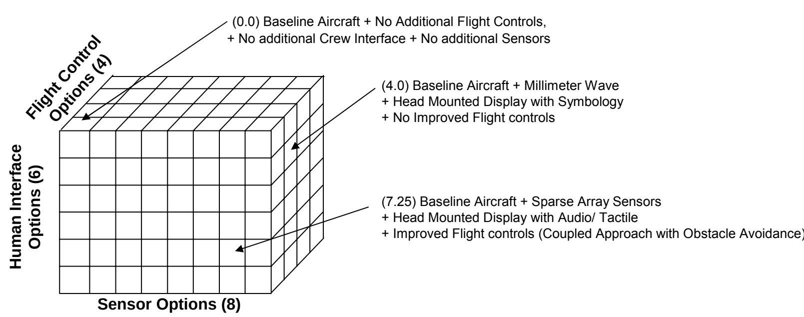
Assess Acquisition Likelihood (Cost Balance, Synergy) → Select Minimum Matrix Sample (Design of Experiments) → Select Additional Configurations Based on Likelihood



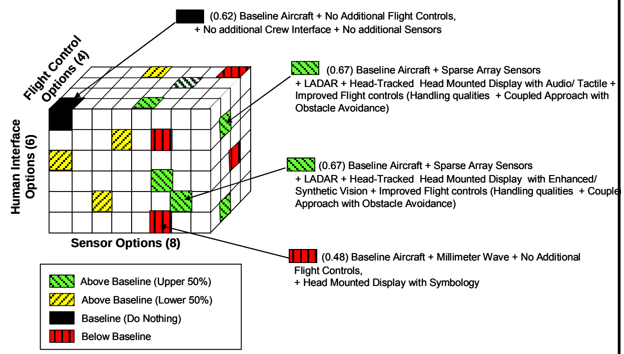
System Configuration Assessment

Generating Relative Solution Value

Assess Quantitative Component Measures (Sensor Range, Weight, etc.) → Assess System Measures (Quantitative & Qualitative) → Generate Individual & Composite Utility Values



Evaluate Solutions



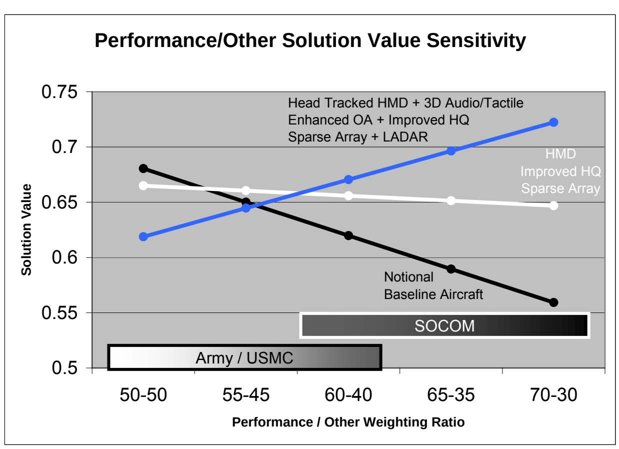
- **Sensors**
  - Millimeter Wave System
    - Low Task Performance
    - High Cost & Size/Weight
  - Sparse Array
    - Moderate Task Performance
    - Low Cost & Size/Weight
  - LADAR
    - High Task Performance
    - High Cost & Size/Weight

- **Human Interfaces**
  - Head Tracked HMD
    - Slim Benefit in High Cost Solutions
    - Slim Penalty in Low Cost Solutions
  - 3D Audio/Tactile
    - Penalty in Low Cost Solutions
    - Neutral in High Cost Solutions
    - High Cost for Stereo ICS

- **Flight Controls**
  - High Benefit
    - Improved Handling Quality -> Enhanced Ops
    - Both > Either

Sensitivity Analysis

Performance vs. Other Factors (Cost, Weight, Etc.)

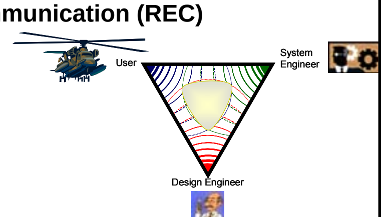


Helicopter Brownout Conclusions

- High Performance System (SOF)
  - Sparse Radar Array + LADAR Sensors
    - Fusion Processing & Persistent 3D World Model
  - Head-tracked Helmet Mounted Display
    - Symbology
    - Enhanced and/or Synthetic Vision
- Lower Performance System (Conventional)
  - Sparse Radar Array
  - Helmet Mounted Display (Symbology)
- Flight Control Systems & Guidance
  - Handling Qualities
  - Flight Directed & Coupled Approach Capabilities
  - Assess and Develop per Aircraft MDS
    - Tiltrotor vs. Helicopter Issues
    - Digital FCS vs. Augmented Mechanical Controls

SE Wisdom

- **Clear measurable requirements are the most useful in situations when they are hardest to generate**
- **There is nothing more potentially complicated than a blank sheet of paper**
  - **It is impossible to effectively consider and choose from an infinite number of design options when developing a new system**
  - **Overcome analysis paralysis with active management and hard decisions to create a manageable number of potential solutions**
- **Use systems engineers with actual ops experience**
  - **Operate in the Region of Effective Communication (REC)**



Questions?